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ABSTRACT

This position statement begins with an outline of the meanings for terms that are central to the session topic at which this paper was presented: inquiry, inquiry learning, scientific inquiry, and scientific method. The central issues of inquiry's place in science education and as a more general educational approach are then discussed. Finally, the relation of this research work to the issues of classroom inquiry strategies is described. Contains 15 references. (WRM)

Inquiry in Science Classes-- Do We Know "How, When and Why"?

by

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Position statement for invited interactive symposium "Inquiry learning: How when and why should science inquiry be brought to the classroom?", Session 4.60 AERA, 1999.

Introduction

We begin this "position statement" with an outline of the meanings we hold for the terms that are central to the discussion points on which the session is to focus, and briefly discuss these meanings and their implications for our thinking. Then we address the central issues for the discussion - how we see "inquiry" in science education and its relevance as an approach for education more generally – in terms of our own research. For the last three years we have worked together on a substantial project whose focus has been on understanding aspects of "inquiry" as it occurs in high school science laboratory classes. We draw on this work to take a particular position with regard to "inquiry" in science classes and the prospects for transfer to other contexts.

Our meanings for "inquiry", "inquiry learning", "scientific inquiry", "scientific method"

- "Inquiry" we see as a generic term appropriate to use in the general dictionary sense: "search for knowledge, investigation, a question" (Macdonald, 1977, p 677).
- "Inquiry learning" then, logically, we use to describe learning/teaching approaches that are consistent with students "searching" for knowledge, "investigating" (by direct experience as in a science laboratory, through researching library sources, etc.) and "questioning" (provided the questions are in some form those of the student).
- "Scientific inquiry" we see as describing that subset of "inquiry" that relates to the ways[1] in which science develops, ways in which it can validly be argued that new concepts are constructed in science, new ideas emerge, new perspectives are formed and justified and accepted.
- "Scientific method" we see as a strange and unhelpful construct whose purging would be of great benefit to science education. We find the emphasis given to ONE mode of intellectual functioning that applies to only a small class of intellectual problems (that are

not the exclusive province of science) to be, at best, strange. In terms of the relationships with the ways science evolves, "scientific method" is nothing more than a strange invention of science text book writers[2].

For us then "inquiry" and "inquiry learning" are very general terms to be used much in the manner of the Progressive Education movement of 60 years ago - while the ideas they convey are highly significant, phrases such as "learning should be active" or "child-centred" have only emblematic value, just as is the case for the current universal emblem "individuals construct their own understanding". Before these phrases can have real use in understanding educational alternatives there must be elaboration and teasing out of detailed meaning, consideration of the impact of contexts, etc (Gunstone, in press).

"Scientific inquiry" we see as a term with very much more restricted meaning than "inquiry". Common use of the term has it closely linked with "scientific method"; hence we do not use "scientific inquiry" and prefer "processes of science" or "scientific processes"[3], terms we use in this discussion. We do not use "scientific method", here or elsewhere. We do not accept that there is any validity (in terms of science) or valid purpose (in terms of student learning in science classrooms[4]) in the use of this notion.

Our research on science laboratory work

We now outline the research project and outcomes on which we are basing our arguments. The essential focus of the research has been to better understand the relations between "content" and "process" in school science laboratories. By "content" we meant the cognitive material whose learning is usually the intention (or at least a central one) of the laboratory activity (eg how light reflects, or what effect does sunlight have on germinating seeds?); by "process" we mean those things often referred to as "scientific processes" – observing, hypothesising, etc (although we certainly do not see these as the province of science alone).

At times in the last 30 years one purpose for science laboratory work (that laboratory work educates about the processes of science and that, in the laboratory, the science student learns about doing science in the manner of the practising scientist) has been so strongly advocated that science curricula focussing on process rather than content have been developed (see for example, Fensham, 1992; Millar, 1991). Implicit in these curricula, and indeed in many statements of this process oriented purpose for laboratory work, is the assumption that these processes of science are independent of content. Such an assumption is questionable (eg

Millar and Driver, 1987), even "controversial" (Lazarowitz and Tamir, 1944, p.94). For example, it has been known for some time that observation, one of these processes, is affected by the perceptions of the observer - that the nature of an observation is dependent on the theories of the observer (Driver, 1973; Gunstone and White, 1981). More comprehensive challenges to the assumption of process-content independence come from two systemic studies of student science achievement - one in California (eg Baxter and Shavelson, 1992), the other in British Columbia (eg Erickson, 1994). As both of these substantial studies were primarily concerned with systemic student science achievement, then process-content relationships were not the prime focus. However, both studies do demonstrate that content and process are not independent, and both also suggest that one significant factor influencing the relationship between content and process is how open-ended is the laboratory activity.

Our research has been an exploration of the approaches of students to open and closed laboratory work, and the ways in which content and process appear to interact in these different forms. By "closed" we mean laboratory tasks where the goal of the activity is highly specified (eg verification exercises) and the apparatus and method are largely given (Step 1, Step 2, and so on). By "open" we mean laboratory tasks where the goal does not determine an approach or in itself indicate when the activity can be considered complete (eg "design and construct a circuit with two light bulbs in series and two in parallel, all shining with the same brightness"), and thus student decisions are required about methods, apparatus, and what counts as completion. The research has been conducted with intact groups in high school science classes (Grades 7-10)[5], undertaking usual class activities with the usual class teacher, and with the close involvement of the teacher in our research planning. In all cases, classes whose lab activities were the focus of our research were observed by one of us for a number of weeks beforehand so that the ways in which the activities were intended to contribute to a teaching sequence could be understood. We have also interviewed students (Grades 10 and 11), both informally as they undertake lab activities and more formally outside the lab to explore their perceptions of nature and purposes of lab work in science.

Our findings and interpretations are in Berry et al. (1999a, 1999b). In brief, examples of these findings (many of which are not surprising) are

- In closed lab tasks: Completion of the task is the overriding focus of many students (even to the extent of ignoring discrepant results); a common secondary goal is to get the "right" answer, a goal that also often overrides approaching the task in the manner intended by the teacher. Those students who do not have the knowledge assumed by the

task are still able to complete the exercise (by following as a recipe the steps on the instructions given), but there is very little evidence of any learning by these students and any mental engagement with the task is extremely rare. One intriguing feature of student lab groups where no student has the assumed knowledge for an activity is the extent to which such groups use visual checks of other groups to monitor their own progress. We found no evidence of any cognitive learning in these groups, and no use of processes beyond what was demanded by the "recipe" they were following.

- In open lab tasks: Those students without the assumed knowledge cannot proceed with the laboratory (eg for the electric circuit example of an open task given above, students who did not understand "series" and "parallel" could not proceed). The perceptions of some students that the teacher will provide the answer before the class ends shapes the ways these students engage (or, better, do not engage) with the task. Task completion is again an overriding issue for most students.
- In open lab tasks with open end points (by which we mean open tasks where students have to design their own lab activity for some general end such as "which of these tablets will dissolve more quickly in hot and cold water"): Many of the points already raised apply here as well. The surprising result for us was to find that, having created an approach for themselves, many students then undertake the task in the recipe manner typical of closed tasks. That is, despite their having created their own method, students often do not feel sufficient ownership of the method to interact with it as the experiment proceeds. In the conduct of such investigations students rarely show any acceptance of the importance of process issues such as repeated and/or careful measurements. In one sense then, it could be argued that after the students have organised their 'approach' on paper, they then revert to simply completing the task in practice.
- Student perceptions: Students who have experienced considerable high school science laboratory work see lab work as making science more interesting and enjoyable, verifying theory, and assisting their understanding of theoretical concepts. To be colloquial, students are very good at indicating the "party line" on lab work. However, many students could not give any specific example of a particular experiment that had assisted their understanding of theory.
- Aim and purpose: There is reason to distinguish between the "aim" of an experiment (the statement often given at the beginning of ritualised forms of laboratory reports; eg "to find out how light affects germinating seeds") and what we term "purpose" (the reasons the teacher has for giving this experience to the class). While many students know the "aim" very few know the "purpose". As a consequence, most students have little or

nothing to say when asked "why are you doing this?". Given the significance we see for metacognition in science learning (eg Gunstone, 1994; White, 1988), this failure to know "purpose" has important limiting implications for student learning from lab work.

How we see "inquiry" in science education and its relevance as an approach for Education more generally

In terms of this question, the central implication of the research discussed above is, we hope, clear – the content whose learning is the focus of the inquiry (or at least is the context for other learning) and the processes that are involved in the inquiry are intertwined. We are currently considering the nature of this intertwining, and what possibilities are consistent with data, ours and others.

For this discussion however, we see an obvious conclusion to be derived from the recognition of the intertwining of content and process. We do NOT see "scientific inquiry as having applicability in teaching other subjects". The content in which the inquiry is embedded is a centrally determining factor in the approaches to learning that are possible for students, and the outcomes students can achieve. To consider "scientific inquiry" as some form of content-independent set of "skills" is to make a grave error. As for "treating inquiry-based science education as a model for education as a whole", we would argue that there is much to do in science contexts before we understand inquiry and the forms of its dependence on content/contexts in science. Even when/if we do understand the "content-process" interactions in science classrooms, any approaches to "transfer" this to other subject matter domains will need clear understandings of the nature of the similarities and differences between the science and other content, contexts, learning expectations, etc.

"Where do we go from here? What are the burning questions we need to address in this area?" First we should accept the complexity of reality in "inquiry" approaches, that it matters WHAT is to be learned as well as HOW it is to be learned, that the "what" and the "how" interact. Second, we need to better understand the nature of these interactions and to not lose sight of the importance of creativity, intuition (Fensham and Marton, 1992) and that science involves people.

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Footnotes:

[1]. Note that the plural is significant for the next point

[2]. There is interesting variation across countries in the extent to which science courses and textbooks embrace this unfortunate construct. There are also within USA interesting variations across curriculum areas in the extent to which it is seen as necessary to begin a course/textbook with a section "What is science?". Many other curriculum areas do not see the need to begin with a corresponding section.

[3]. We recognise that "scientific processes" has the problem of implying that things such as observing, hypothesising are specific to science when they of course are not.

[4]. Arguments about simplifying ideas in order to assist student learning do not impress us here. The principle of simplification of course we regard as essential for science education at all levels. However any educationally legitimate simplification has to have some substantive links with the concept/phenomenon being simplified. "Scientific method" we assert has no such substantive links with the reality of science and its evolution.

[5]. High schools in the Australian state of Victoria (the site of this research) have students for Grades 7-12.

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